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Design and Construction of a Miniature Solar Power System to Operate Meteorological Instruments

Kenneth G. Bird[1]

The relatively inexpensive solar power system improves meteorological instrument reliability by maintaining an optimum operating voltage. System voltage and charging capabilities are easily modified to fit specific power requirements for other low-voltage applications.

Keywords: Meterological instruments, solar power

Size D, nonrechargeable batteries are often used to power meteorological instruments at remote locations. Low battery voltage, particularly during extremely cold weather, is a major cause of instrument failure, and thus, of record loss. This problem has been eliminated by changing from nonrechargeable batteries to a power pack, trickle-charged by a mini-solar panel. The system will provide more than 100 mA per day at 4 V, or enough power to operate up to 10 electric clocks.

Components

Solar Panel

The solar panel is constructed from small silicon chips that convert sunlight into electrical energy (fig. 1). Each 2- by 2-cm chip has an output rating of 100 mA at 0.45 V. Nine chips are connected in series to charge batteries to about 4 V. A diode must be placed in the circuit to prevent battery discharge through the solar panel when charging voltage is less than battery voltage. The solar cells begin to generate electricity when solar energy levels reach about 10% of full midday radiation. Some charging occurs even during cloudy weather.

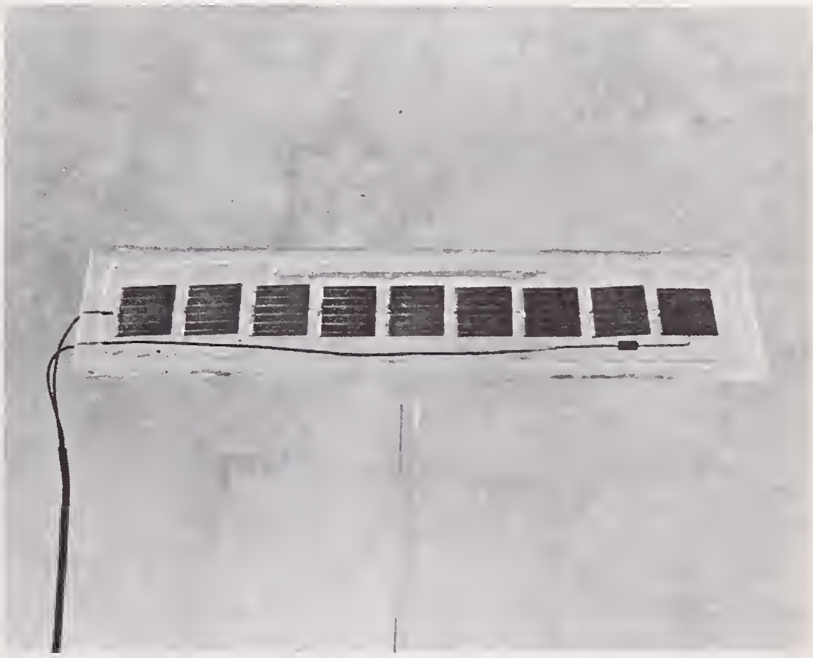


Figure 1.—Miniature solar panel showing location of blocking diode in lead wires to battery pack.

[1]*The author is a Range Technician, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, with headquarters at Fort Collins in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Laramie, Wyo., and was supported in part by the Bureau of Land Management, U.S. Department of the Interior.*

Battery Pack

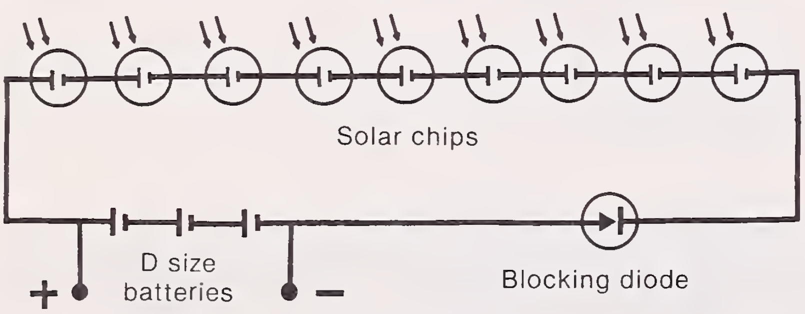
The battery pack stores electrical energy converted by the solar panel. It consists of three, D-sized, nickel-cadmium, rechargeable batteries connected in series; battery spring contacts, and a weatherproof container. Because nickel-cadmium batteries with a 4-Ah rating have a much longer service life, they are suggested for use in the battery pack instead of smaller capacity batteries. Batteries with a 1.2-Ah capacity began to fail after 1 year in field service.

Electric clocks used in meteorological instruments have an average current drain of about 0.35 mA or 8.4 mAh per day. The solar panel has an average output of about 100 mAh on an average winter day in southern Wyoming. Therefore, the system will operate about 10 electric clocks indefinitely in this area. Exact capabilities of the system, however, depend upon the solar regime at a particular site. For applications where power consumption exceeds the equivalent of 10 electric clocks, adding 1 more silicon chip to the series string will provide enough additional charging current to operate approximately 5 more electric clocks.

System Assembly

Solar Panel

Step 1.—Connect the nine silicon chips in series by soldering a short piece (about 1 cm) of stranded, no. 26 copper wire from the positive side of one chip to the negative side of the adjoining chip (fig. 2). Using the short piece of wire to connect chips results in a gap of 2-3 mm between them, which allows each chip to independently expand and contract as temperature changes. The wire need not be insulated. All connections should be thoroughly cleaned before and after soldering to insure a solid bond and prevent corrosion. Use only rosin core solder.



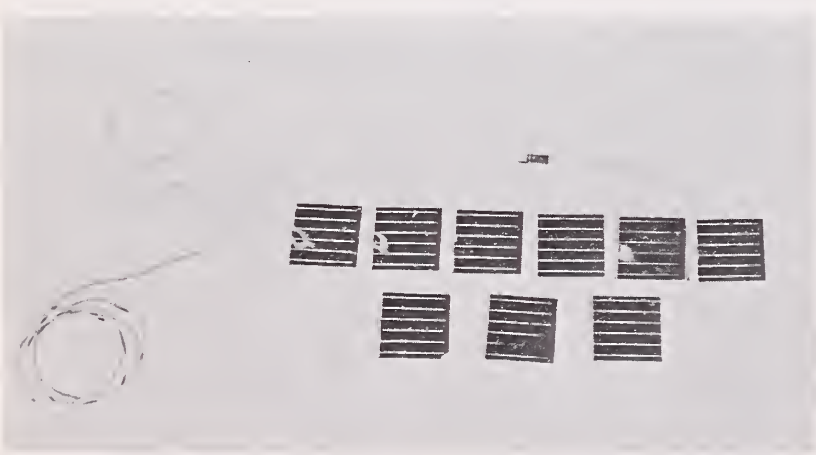


Figure 2.—(a) Schematic diagram of solar power system. (b) Materials needed for construction of a miniature solar panel. Individual cells in the top row have been connected in series; individual solar cells and the placement of an interconnecting wire between individual cells is visible in the lower row.

Step 2.—Solder the diode's anode lead to the positive end of the silicon chip string.

Step 3.—Solder 50 cm of no. 26, insulated, stranded, copper wire to the cathode lead of the diode and another 50 cm of wire to the negative end of the silicon chip string. Color coded wires aid in identifying positive and negative ends of the solar panel.

Step 4.—Center a thin strip of clear silicone seal along the center of a 5- by 23-cm sheet of Plexiglas. Center the silicon chip string above the Plexiglas sheet and gently press the back side of the string into the silicone seal.

Step 5.—Apply a bead of silicone seal around the perimeter of the Plexiglas, thick enough to extend above the surface of the solar chips. The two lead wires from solar chips exit the panel at one end and are positioned so that they do not obstruct the surface of any chip.

Step 6.—Center the second 5- by 23-cm sheet of Plexiglas over the first sheet, and then press down to compress the bead of silicone seal applied to the bottom sheet of Plexiglass in step 5. The silicone seal should be thick enough to prevent the top sheet of Plexiglas from touching the silicon chip string and will form a watertight seal.

Step 7.—Allow the seal to dry for 24 hours.

Step 8.—Attach an adjustable mounting bracket to the back of the solar panel for tilt adjustment. A small hinge with the pin replaced by a bolt and nut works well.

Battery Pack

Step 1.—Cut and assemble four pieces of wood, plastic, or other suitable nonconducting construction material to form a waterproof container with inside dimensions of 3.5 by 3.5 by 19 cm (fig. 3).

Step 2.—Cut two end pieces the same size as the outside dimensions of the container.

Step 3.—Drill two holes 5 mm in diameter in each end piece for the threaded rods which hold the battery pack together. Holes are located 2 cm from the center of the end piece, on a diagonal towards opposite corners (fig. 3). A third hole, large enough for lead wires from the battery, is drilled in one end piece. This hole is also placed 2 cm from the center of the end piece, on a diagonal towards one of the remaining corners.

Step 4.—Solder 50 cm of no. 26, insulated, stranded copper wire to each battery spring contact. Glue a battery spring contact to the center of each end piece.

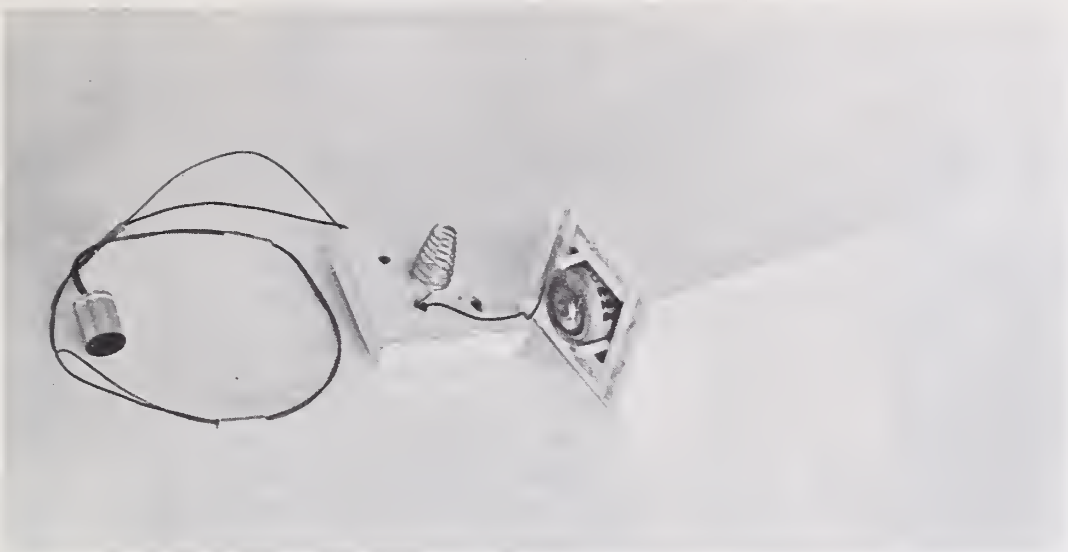
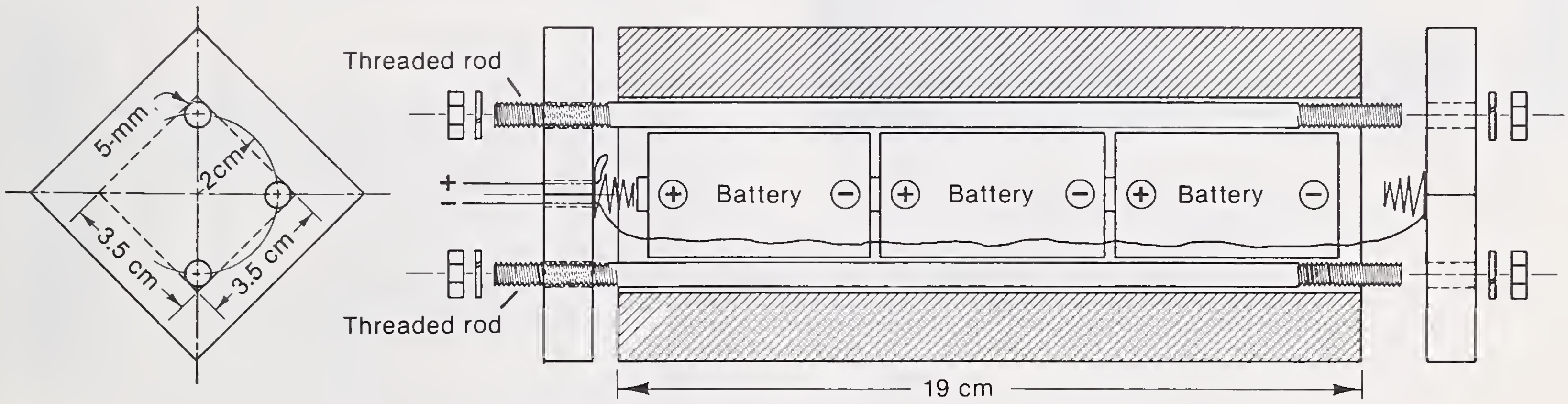


Figure 3.--(a) Photo of completed battery pack. (b) Diagram of battery pack, spring contact, threaded rod, and rechargeable size D batteries.



Step 5.—Permanently attach the end piece containing the two holes for threaded rods to the battery box. The battery contact should face the interior of the box. The lead wire extends through the interior of the box.

Step 6.—Insert three fully charged batteries into the box in series. Run both battery leads through the third hole in the end piece not attached to the box. Insert the two threaded rods through the permanently attached end piece and down the length of the box. The remaining end piece is then securely bolted to the box so that the battery is in contact with the spring contact.

Step 7.—Check battery leads for proper voltage and polarity.

Step 8.—Caulk all holes with silicone seal and paint the battery pack, if desired.

Field Installation of the Solar System

The solar panel must be installed where no obstructions block solar radiation and above the maximum snow accumulation level (fig. 4). The solar panel and battery pack lead wires are connected observing proper polarity. The final step in placing the solar power system into service is to connect it with electric clocks that operate meteorological instruments. The clocks may be connected directly to the power pack, but a more serviceable arrangement is to make the connection at a terminal block. The use of a terminal block simplifies connection or removal of meteorological instruments from the power pack, especially if more than one instrument is in use.

The solar panel is mounted with the solar chips facing south and the longitudinal axis oriented in an east-west direction. The exact southerly tilt of the panel from horizontal is not important except at installations where power consumption approaches maximum charging capacity of the panel in winter. An average setting for the central section of the United States is to tilt the panel face 45° from horizontal in a southerly direction. The panel can be aligned more precisely by tilting it 1° from horizontal for each degree of latitude at the installation site. The optimum alignment for year-round power generation must be done on-site, at noon, at the vernal or autumnal equinox, using a milliammeter. The meter is connected in series with the output lead from the solar panel. The southerly tilt of the panel is then adjusted for maximum current output.

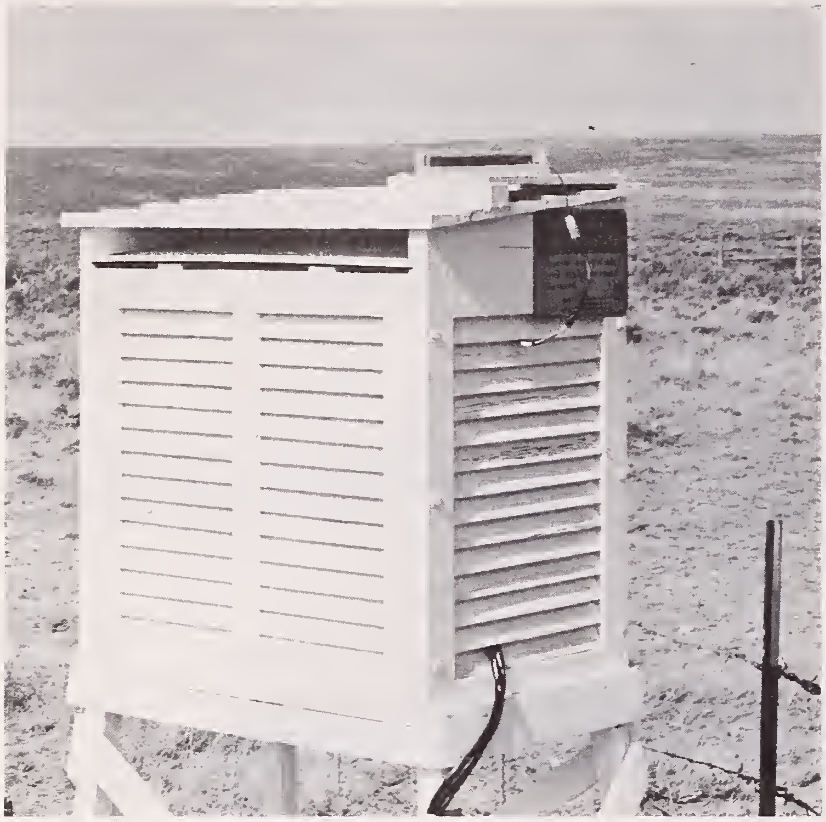


Figure 4.—Field installation of miniature solar panel on the roof of a weather bureau instrument shelter.

List of Materials[2]

Quantity	Item	Cost
3	Eveready CH4 battery or equivalent @ $6.32	$18.96
9	solar chip 2 cm² @ $1.49	13.41
2	3-mm-thick, clear Plexiglas sheet 5 by 23 cm	2.50
1	tube clear silicone seal	2.50
1	1N4000 series diode	0.25
2	battery spring contact @ $0.25	.50
2	25 cm length of 5 mm continuously threaded rod @ $0.25	.50
4	5 mm nut and washer @ $0.05	.20
1	2 m length of no. 26, insulated, stranded, copper wire	.25
1	25 cm length of rosin core solder	.10
	Total cost	$39.17

[2]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

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